ATMOSPHERIC H_2O AND THE SEARCH FOR MARTIAN BRINES Zent, A. P., F. P. Fanale and S. E. Postawko, Planetary Geosciences Division, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hi. 96822

Abundant martian brines would have significant implication for current theories of volatile migration on Mars, since, although the presence of metastable brines is quite plausible, any brine in the reasonably near surface should be completely depleted on a timescale short in relation to the age of Mars. Their presence would strongly imply either large-scale subsurface mass transport, or juvenile outgassing rates significantly in excess of those believed currently possible. Any H_2O transport mechanism with sufficient capacity to maintain a near-surface brine in the martian regolith must be the dominant transport mechanism in the martian subsurface. As such, it is important to determine whether brines exist in the martian subsurface, for our current paradigm for understanding martian volatile regime will require substantial alteration if they are found to exist.

There are no stable brine systems on Mars today. The net annual escape flux of H_2O would be significant at all latitudes where the subsurface temperature exceeds the eutectic of chemically reasonable brines (2). Thus, if any brines do exist, they are constantly losing H_2O molecules to the atmosphere at a rate that depends upon the depth at which the melting occurs, the local thermal regime, and the porosity and mean pore size of the overlying regolith. The loss of H_2O molecules from a regolith source to the atmosphere, which supports only a very low ambient H_2O abundance (controlled by polar temperatures), may provide a means of detecting Martian brines, if they exist. We will discuss, in qualitative terms, some of the factors which would affect the utility of atmospheric H_2O observations as tools for detecting, or refuting the existence of, Martian brines. That is, it is important to understand whether unreasonable near-surface stratigraphy needs to be postulated to prevent the water flux to the atmosphere from any putative brine system from exceeding that allowed by the MAWD data. These factors may be broadly divided into two categories: those peculiar to the brine and its immediate environment, and those that are determined by the position of the system within the global environment.

The Brine. In our initial analysis (1), we found that for most chemically reasonable brines that might undergo annual melting, the annual average mass loss rates are on the order of 10^{-2} g H_2O yr^{-1} down to 10^{-4} g H_2O yr^{-1}. This range of net annual escape fluxes applies to a remarkably large percentage of the plausible shallow, seasonally active brine systems; there are plausible brine systems which are too deeply buried to have any annual cyclicity imposed on them at all. We will return to them briefly below. The escape of H_2O molecules from a melting interface at depth Z falls off as Z^{-1}, approximately in accordance with Fick's Law; the escape flux achieves $\sim 10^{-2}$ g H_2O yr^{-1} at depths of 30cm or less, for a nominal 50% porosity. The porosity of the regolith also plays a significant role in determining the escape rate of H_2O, with the flux increasing almost as the square of the porosity. A brine which releases 10^{-4} g H_2O yr^{-1} to the atmosphere through a regolith with 10% porosity, will release an order of magnitude more H_2O per year at a porosity of ~30%. The mean pore size of the regolith is not of great importance in determining escape fluxes, unless the mean free path of the H_2O becomes substantially greater than the pore size. Under such conditions, Knudson diffusion is the dominant transport mechanism and the escape flux falls off with pore size. With respect to both of these topics, the natural tendency of groundwater to leach materials from its surroundings and precipitate them on evaporation should not be ignored. Such a process should produce a kind of duricrust, much like those observed by Viking; however, duricrust may also decrease mean pore size and bulk porosity of the regolith. In principle, a duricrust cap could allow metastable brine systems to exist without violating the MAWD data.

Another factor which plays a role in determining the detectability of subsurface H_2O sources is their areal extent. Very concentrated sources, even though they may be supplying H_2O at a prodigious rate, are unlikely to be detected because of resolution problems.

There is a conflicting set of requirements involved in atmospheric H_2O detection of brines, because those systems which are best suited to identification are also the shortest-lived. Loss of H_2O molecules results in recession of the melting interface until the seasonal thermal wave is no longer sufficient to cause melting, unless resupplied from depth. At depths of ~1 m, average mass loss rates of 10^{-3} g H_2O cm^{-2} yr^{-1}, the recession rate of a brine would be on the order of 10^5 yr m^{-1}. Brines below about 2m should be quite well insulated from the annual thermal wave. Such deep brines however cannot be invoked to explain seasonal variability in radar reflectivity measurements.

There are some brines which have eutectics below the annual average temperature at low latitudes. Such brines could conceivably remain liquid throughout the martian year at depths greater than a few meters. These putative brines would remain liquid and would be entirely undetectable, with mass loss rates on the order of a fraction of a percipitable micron per year, and well below the penetration depth of radar signals.

The composition of the brine system is also critical. Melting begins with a brine of eutectic composition and continues isothermally until the supply of one of the components is exhausted. As long as ice is present in the system, the vapor pressure over the brine will equal the vapor pressure over ice at the temperature of the system. However, once all the ice has melted, the vapor pressure over the brine will be lower than it would be over ice at the same temperature. Therefore incomplete melting of the brine, which results from a bulk composition significantly less saline than the eutectic composition, favors higher escape fluxes and hence detectability.

A brine which has a high evaporative loss to the atmosphere, for whatever reason, will be most detectable. High loss rates may be due to a highly porous overburden, a water-rich brine system, or a shallow melting interface. High salinity brines, capped by a great deal of overburden, or by overburden of low porosity, will hide brines effectively from atmospheric detection.

The Environment Environmental factors are those which are approximately independent of the existence of the brine, such as the local thermal regime, the background column abundance of H_2O and the regional wind velocities.

Atmospheric signatures of escaping brines will have greater absolute magnitude at low latitudes because the warmer melting interface will support a greater equilibrium water vapor abundance. Naturally, escape fluxes become more seasonally dependent as latitude increases, and the annual average escape flux decreases. Higher escape fluxes favor detection, and low latitude brines should be more easily detectable.

Detection is also aided by the escape of H_2O molecules into a low background abundance of water vapor, since it is the difference between the escaping and ambient H_2O that is indicative of a regolith source. Therefore, in general, the likelihood of detecting a brine increases as one moves away from the north pole, although again, seasonal variations in local H_2O abundances will affect the outcome of any search.

H_2O molecules which escape from a seasonal vapor source in the regolith to the atmosphere will be dispersed by the winds. The lower the local wind velocities, the more likely that an excess abundance of H_2O will accumulate in the atmosphere.

The most likely location for brine detection, assuming the same brine exists everywhere on the planet, is one in which the subsurface temperatures are high, while the atmospheric H_2O abundances are low. On Mars, this is most closely approximated during low southern latitudes near perihelion. Temperatures are warmer at that time than in the northern hemisphere summer because perihelion occurs during southern hemisphere summer. At most locations on the planet though, peak atmospheric H_2O abundances are more closely correlated with peak surface temperatures. Unfortunately, the low southern latitudes also experience their peak annual wind velocities near perihelion.

We conclude that the prospect for detection of a subsurface brine via atmospheric water vapor measurements is marginal, for four reasons. 1) There is an inherent inadequacy in using escape to the atmosphere to detect regolith water sources, since one does not really observe the source at all, but a product of the system's dissipation. Those brines which are best suited for detection are therefore the same ones that are most unstable, and hence have the shortest mean lifetimes. 2) Not only the mass loss itself, but processes which take place concurrently with evaporation also tend to reduce the escape flux; evaporation leads to concentration of salts in the brine which depresses the equilibrium water vapor abundance at the melting interface, and hence the escaping flux. Continued evaporation then leads to deposition of a duricrust-type deposit which may have the effect of decreasing the porosity of the overburden, further decreasing the escape flux. For most reasonable putative brine systems, this process requires no more than about 10^5 years. 3) Those brines which do not suffer from rapid degradation, and are consequently longest-lived, are also those least detectable since they are either found at great depth, or are capped by a very low porosity overburden. 4) The environmental factors which are most important in determining the detectability of such a system (i.e. temperature and atmospheric water vapor) tend to be correlated in a manner opposite that which is best suited to facilitate brine detection.

REFERENCES
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